

The Muscular System

Our Bodies in Motion

The Muscular System

Review of Muscle Tissues

- Three Types:
 - **Skeletal:** long thin multi-nucleated muscle fibers called striations, controlled voluntarily, fatigue easily
 - **Smooth:** lack of striations, controlled involuntarily, make up the walls of visceral organs and blood vessels and contract in a slow sustained manor
 - **Cardiac:** network of fibers separated by intercalated discs, only found in the heart

The Muscular System

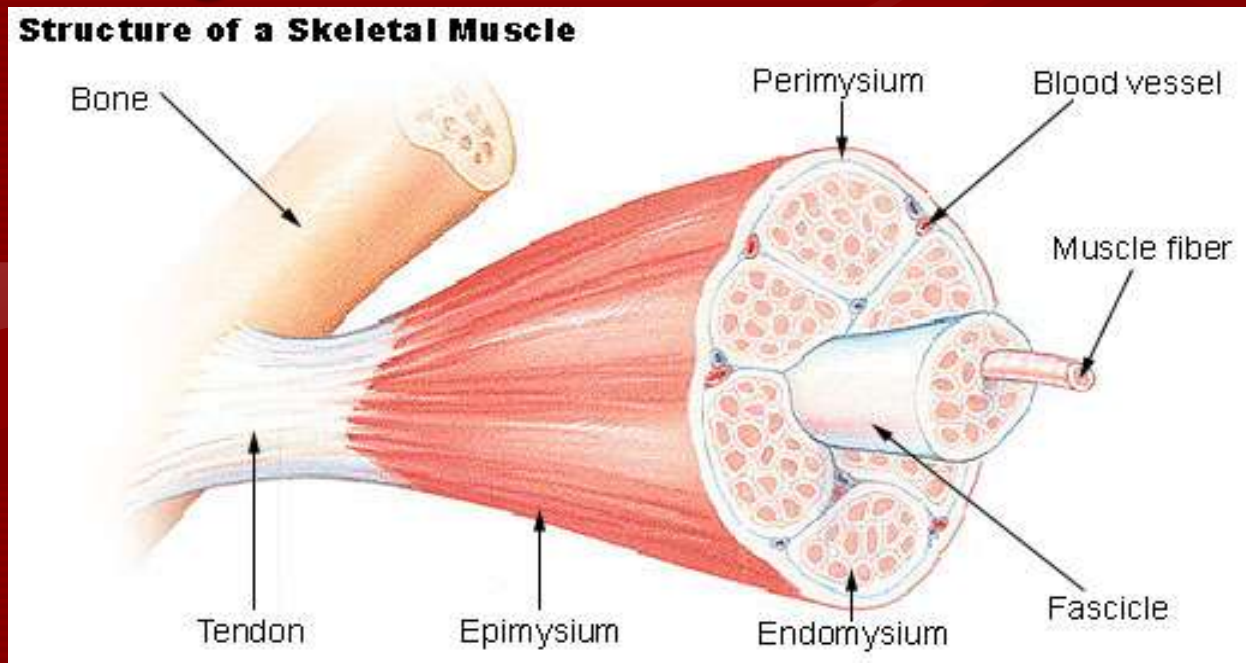
Common Functional Characteristics

- *Excitability* or the ability to receive and respond to stimuli.
- *Contractility* or the ability to shorten forcibly when stimulated.
- *Extensibility* or the ability to be stretched or extended.
- *Elasticity* or the ability to bounce back to original length after being stretched or shortened.
- HowStuffWorks "Skeletal Muscle"

The Muscular System

Skeletal Muscle Gross Anatomy

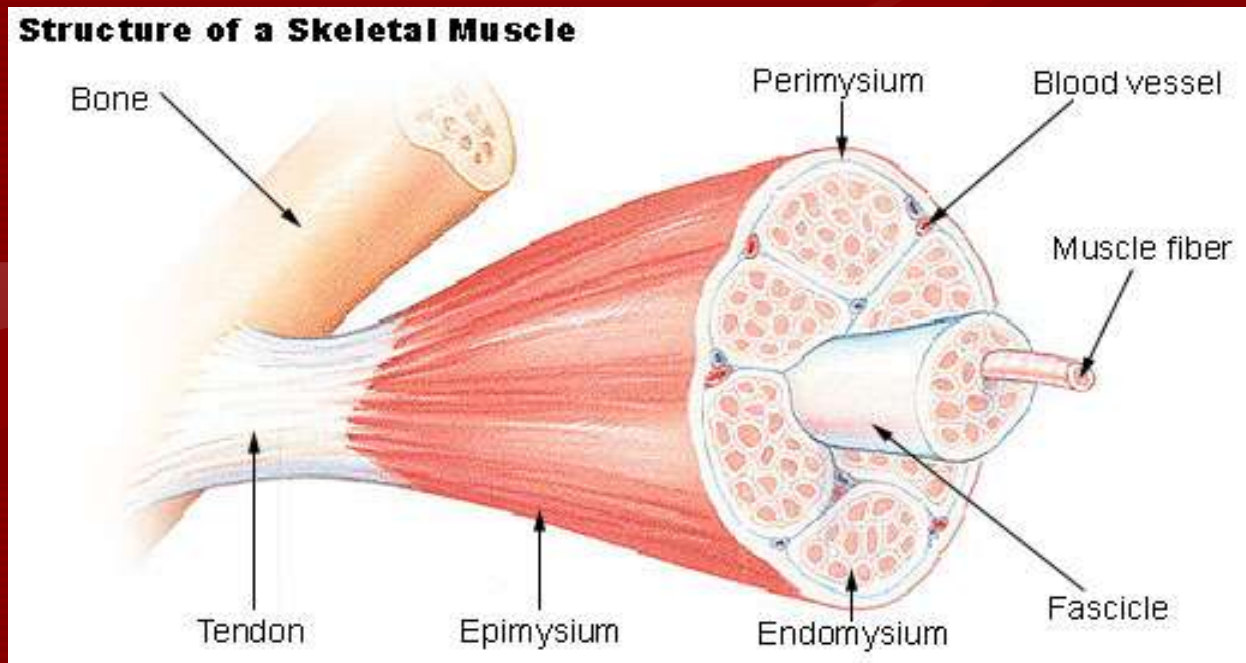
- Each *skeletal muscle* is an organ made up of skeletal muscle fibers, connective tissue coverings, blood vessels and nerve fibers.



The Muscular System

Skeletal Muscle Gross Anatomy (cont)

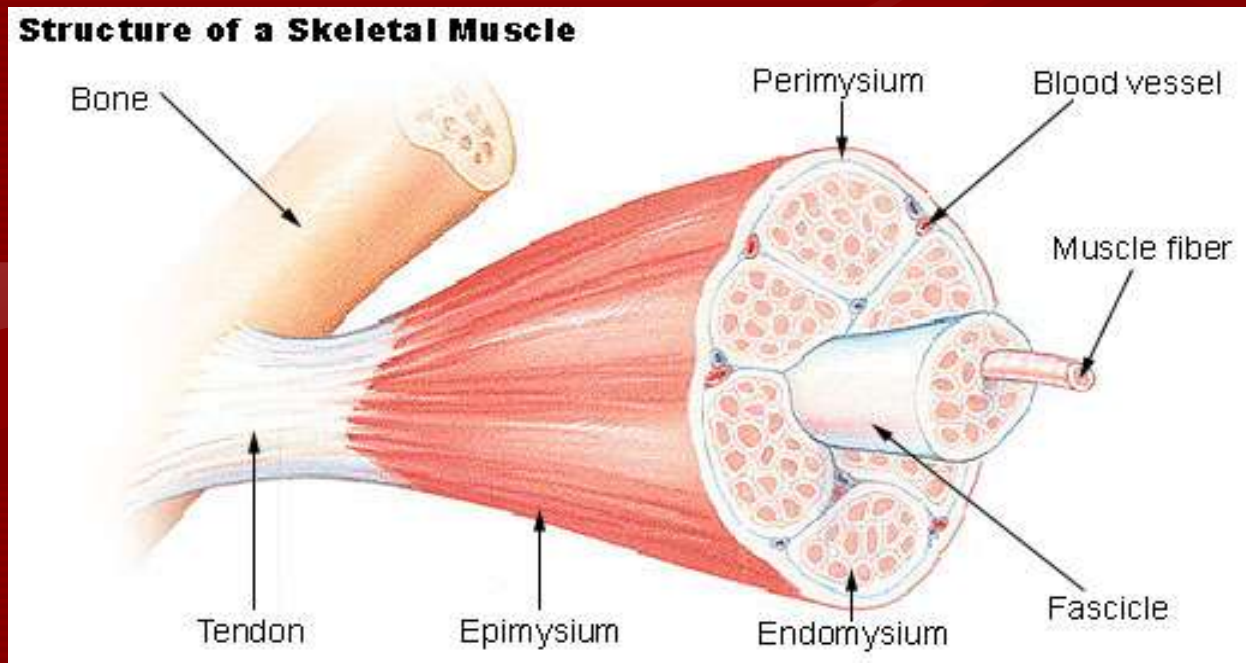
- Each muscle fiber (aka cell) is wrapped in a thin delicate layer of CT called *endomysium*.



The Muscular System

Skeletal Muscle Gross Anatomy (cont)

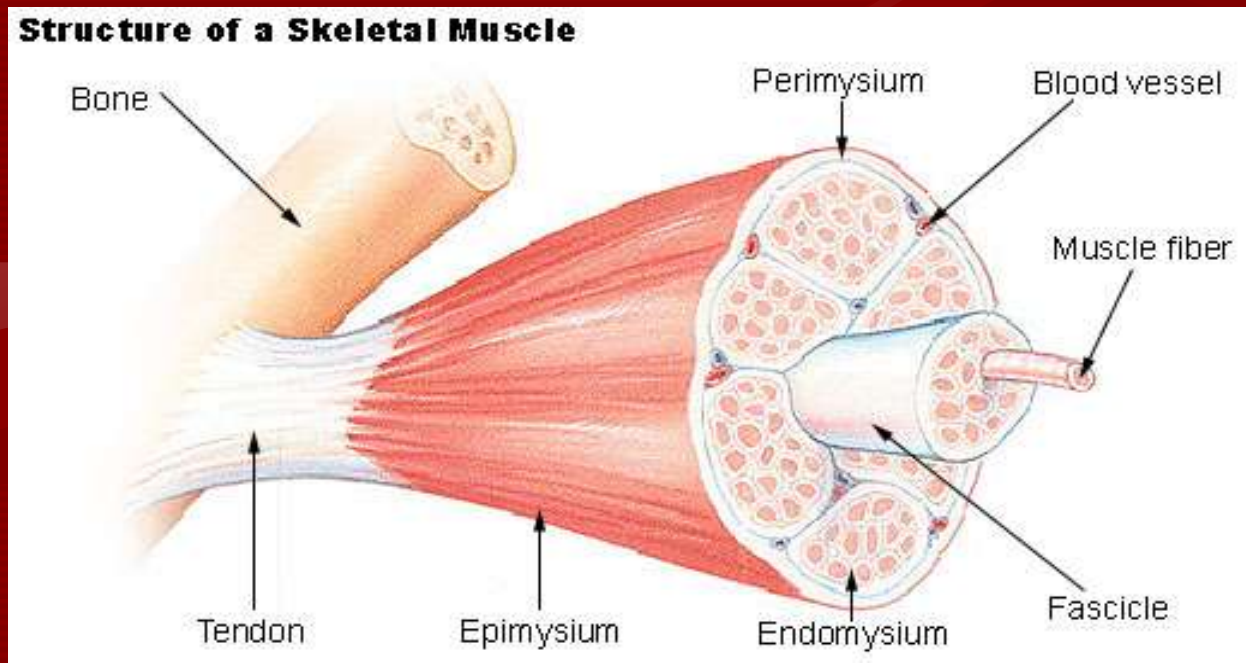
- All of these groups are wrapped together in *perimysium* to form *fascicles*



The Muscular System

Skeletal Muscle Gross Anatomy (cont)

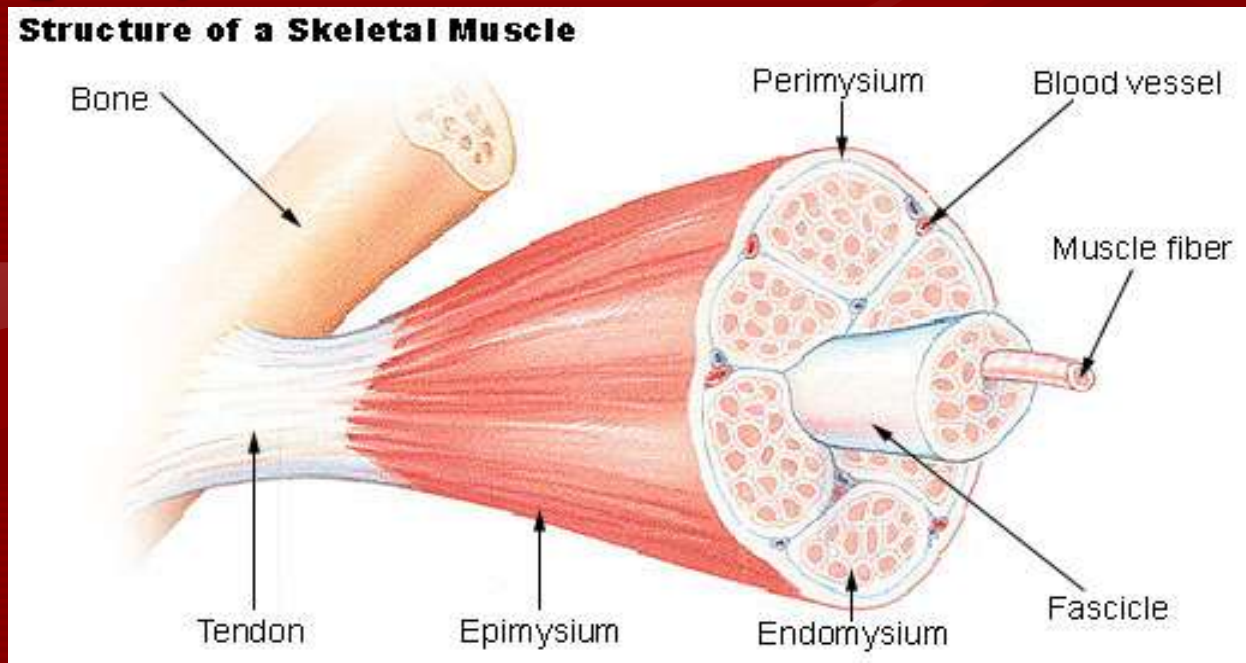
- Then many fascicles are bundled together into skeletal muscles.



The Muscular System

Skeletal Muscle Gross Anatomy (cont)

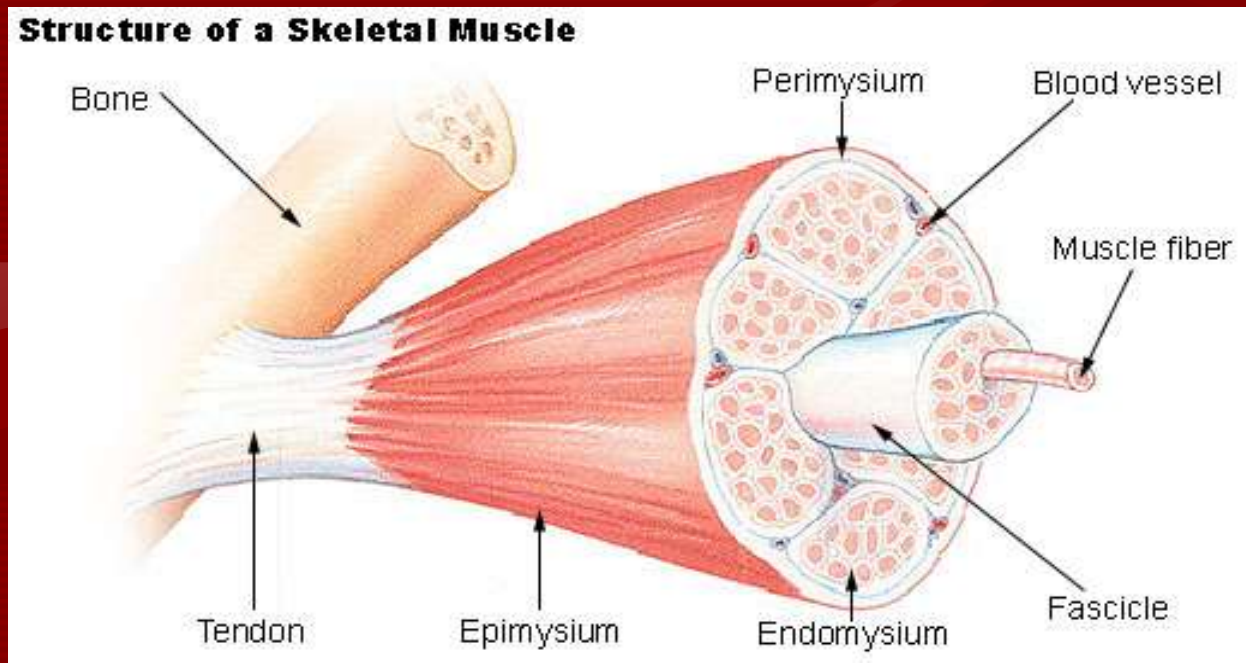
- The skeletal muscles are bundled together by a tough fibrous layer of CT called *deep fascia* or *epimysium*.



The Muscular System

Skeletal Muscle Gross Anatomy (cont)

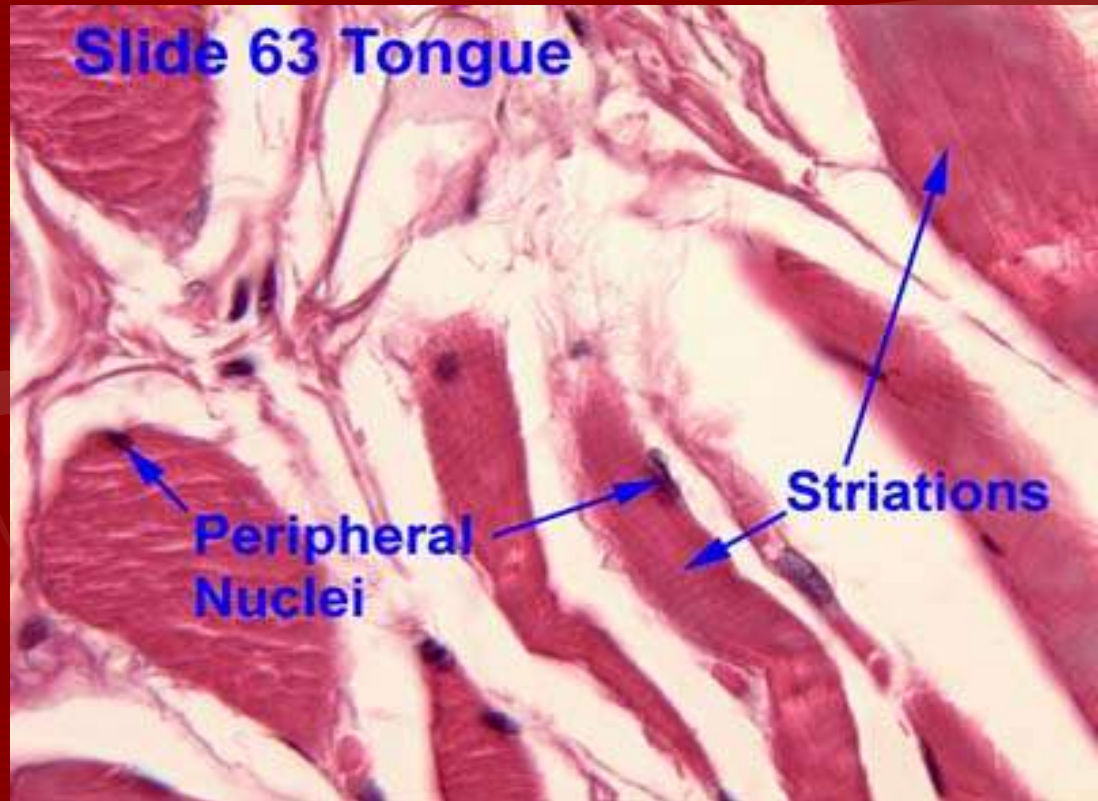
- The deep fascia may extend past the length of the muscle to form *tendon*.



The Muscular System

Skeletal Muscle Microscopic Anatomy

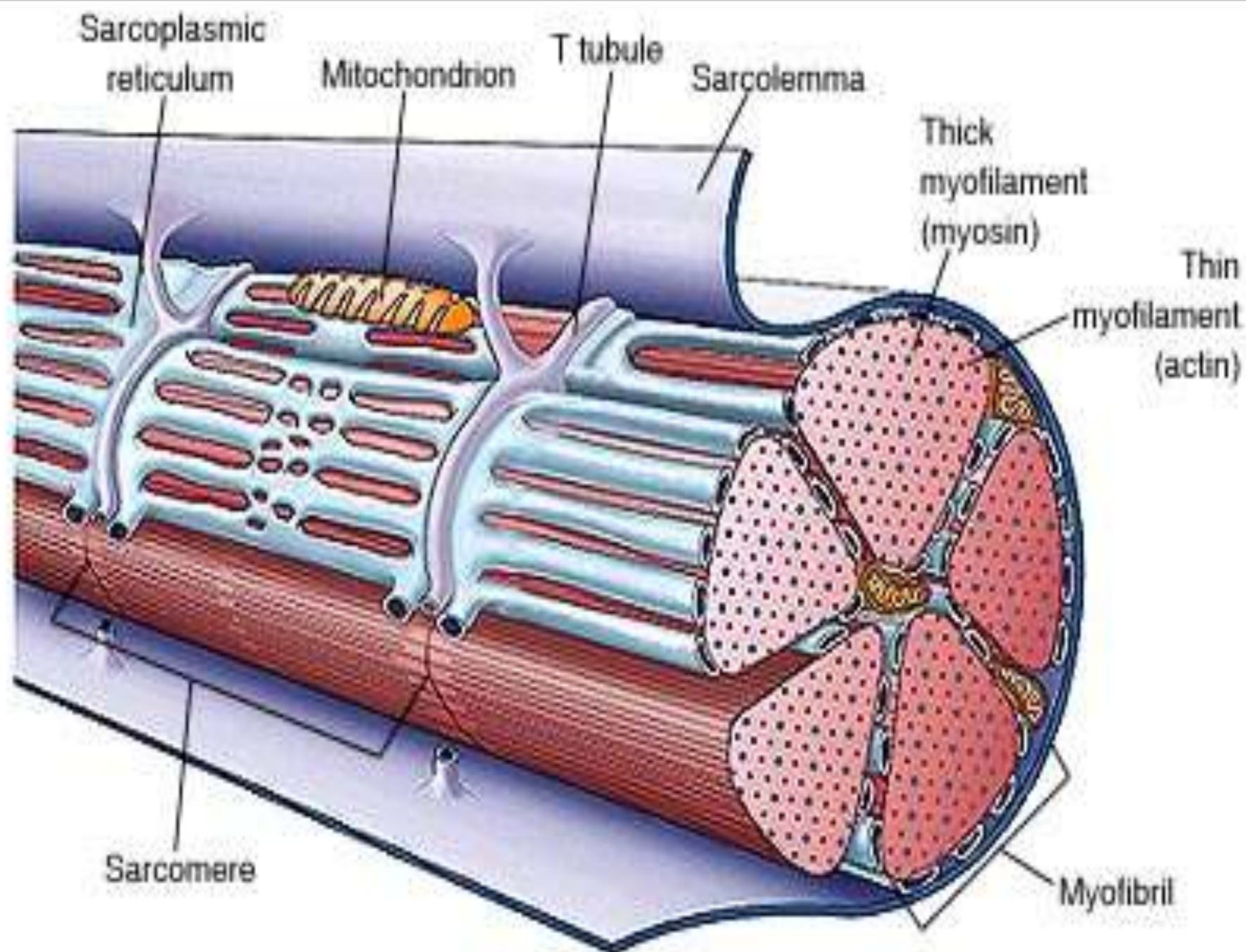
- The muscle fiber is a long thin cell called a *striation*.



The Muscular System

Skeletal Muscle Microscopic Anatomy (cont)

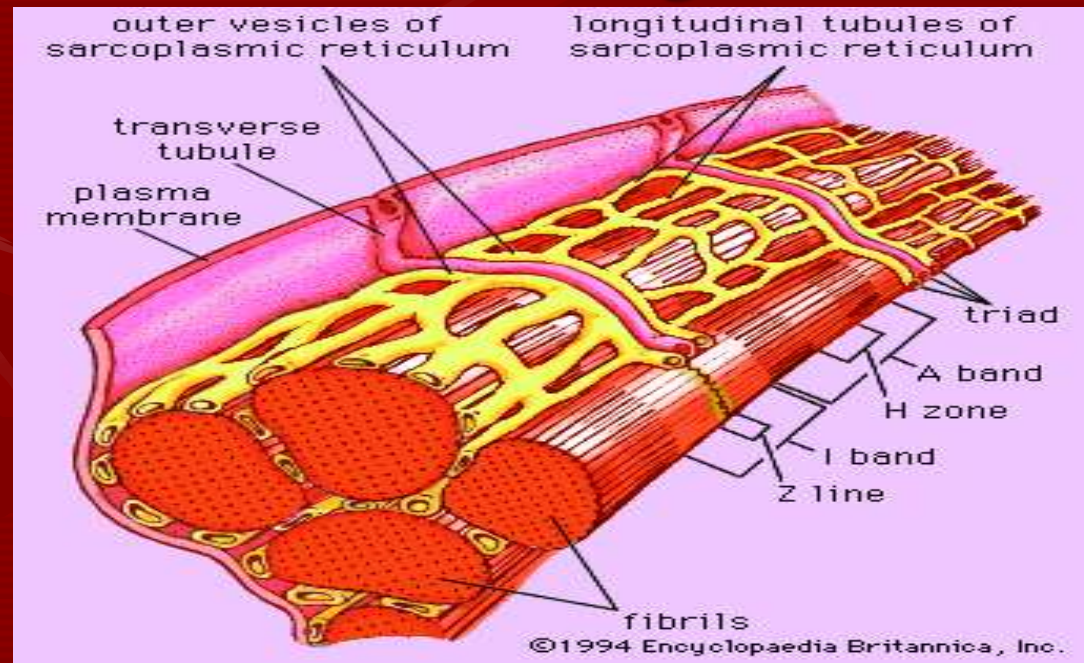
- Each muscle fiber is made up of *myofibrils*.
 - Each muscle fiber is made up of two types of *protein filaments*.
 - **Thick** filaments are composed of the protein *myosin*.
 - **Thin** filaments are composed of the protein *actin*.



The Muscular System

Skeletal Muscle Microscopic Anatomy (cont)

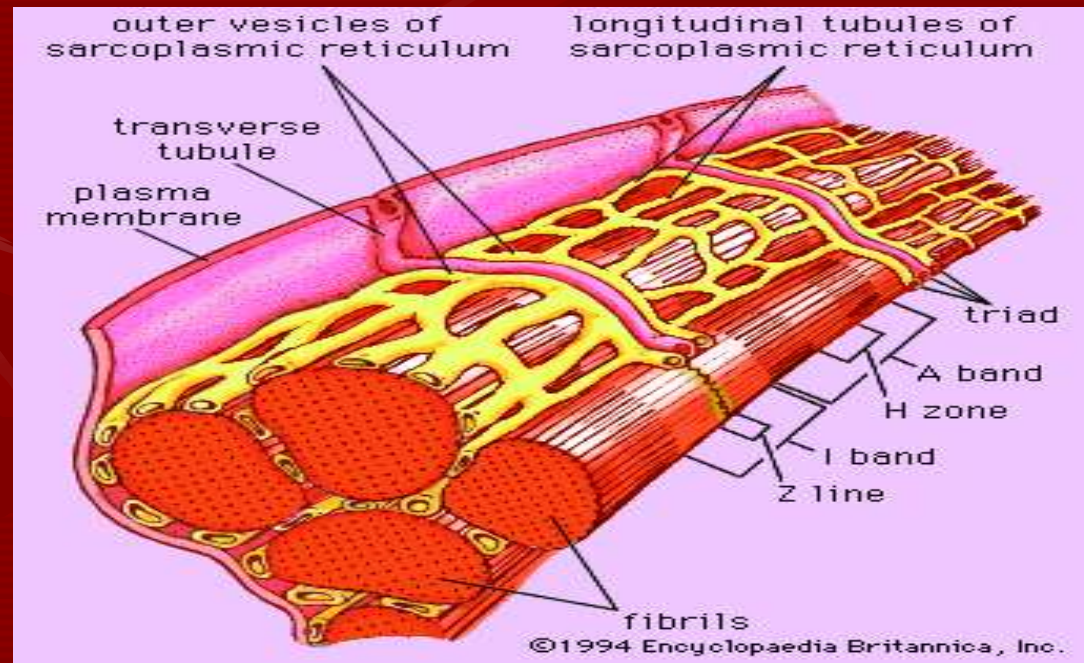
- Striations are caused by the arrangement of thick and thin filaments within the myofibrils, as dark bands called **A-bands** and light bands called **I-bands**.



The Muscular System

Skeletal Muscle Microscopic Anatomy (cont)

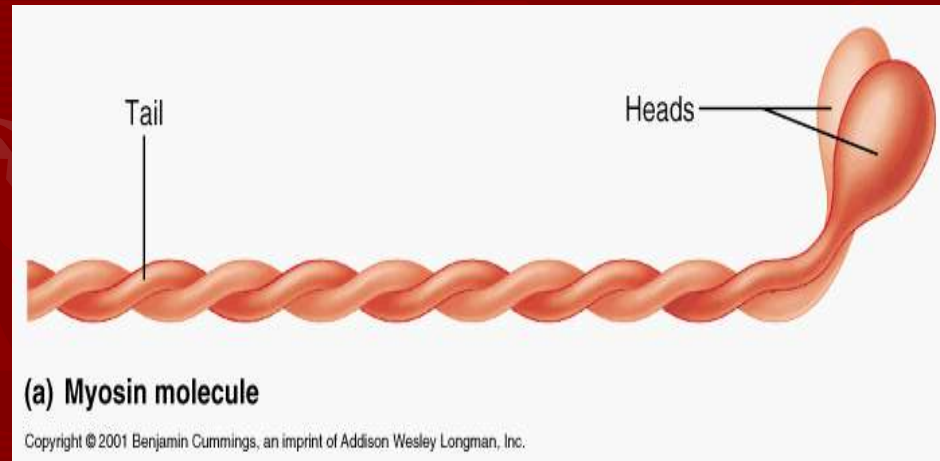
- The length of each myofibril is divided into *sarcomeres* which meet each other at an area called the **Z-line**.



The Muscular System

Molecular Anatomy of Myofilaments

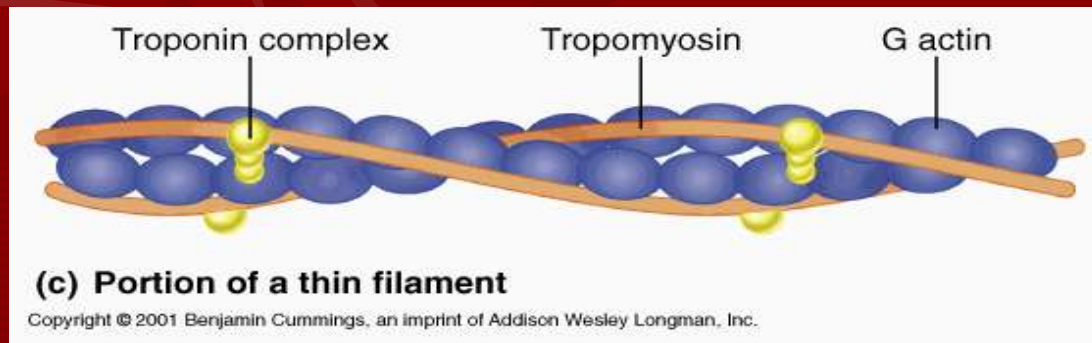
- *Thick filaments* are made up of a rod like tail that terminate in two globular heads or cross bridges which interact with active sites on thin filaments.



The Muscular System

Molecular Anatomy of Myofilaments

- **Thin filaments** have a coiled helical structure resembling a twisted strand of pearls.
 - Two proteins called *tropomyosin* and *troponin* make up **actin** and they help control its interaction with myosin during contraction.



The Muscular System

Molecular Anatomy of Myofilaments

- Within the sarcoplasm (cytoplasm of striated muscle cells) of a muscle fiber, there are two specialized membranous organelles:
 - 1.) The *sarcoplasmic reticulum (SR)* is the same as the endoplasmic reticulum in other cells.

The Muscular System

Molecular Anatomy of Myofilaments

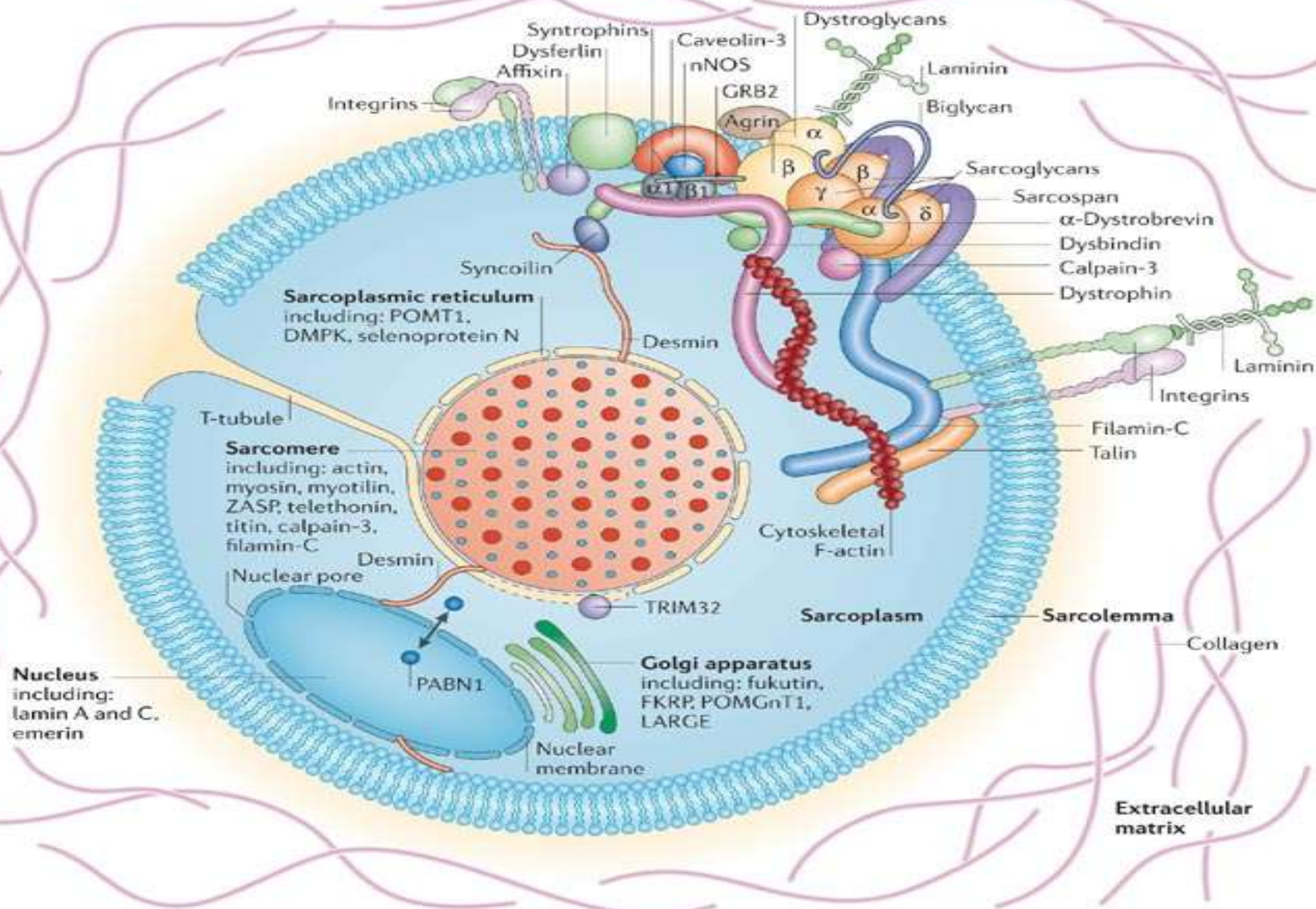
- Sarcoplasmic Reticulum
 - It is a network of membranous channels that surround each myofibril and runs parallel to it.
 - The SR has a high concentration of calcium ions.
 - When the muscle is stimulated this “storehouse” of calcium ions are released into the sarcoplasm.

The Muscular System

Molecular Anatomy of Myofilaments

2. The *transverse tubules (TT)* are sets of membranous channels that extend into the sarcoplasm.

- TT's are filled with extra cellular fluid and extend deep within the cell.
- Each runs between two enlarged portions of SR called cisternae.



The Muscular System

Molecular Anatomy of Myofilaments

- SR and TT are involved in activating the muscle contraction mechanism.

The Muscular System

Anatomy of a Muscle Contraction

- The contraction of skeletal muscle is a biological process which is not completely understood.
- The best theory for the action of a muscle contraction is **“The Sliding Filament Theory”**.
- The thin filament will slide past the thick filament.

The Muscular System

Sliding Filament Theory

Step 1: Calcium ions will bind to and move the tropomyosin (protein which blocks binding sites).

Step 2: The actin and myosin will bind at the cross bridges.

The Muscular System

The Sliding Filament Theory

Step 3: The cross bridge will pull the actin filament towards the myosin.

Step 4: An ATP molecule will bind to the cross bridge at which time a phosphate will be broken off.

Step 5: The energy is used to remove the tropomyosin from the calcium ions.

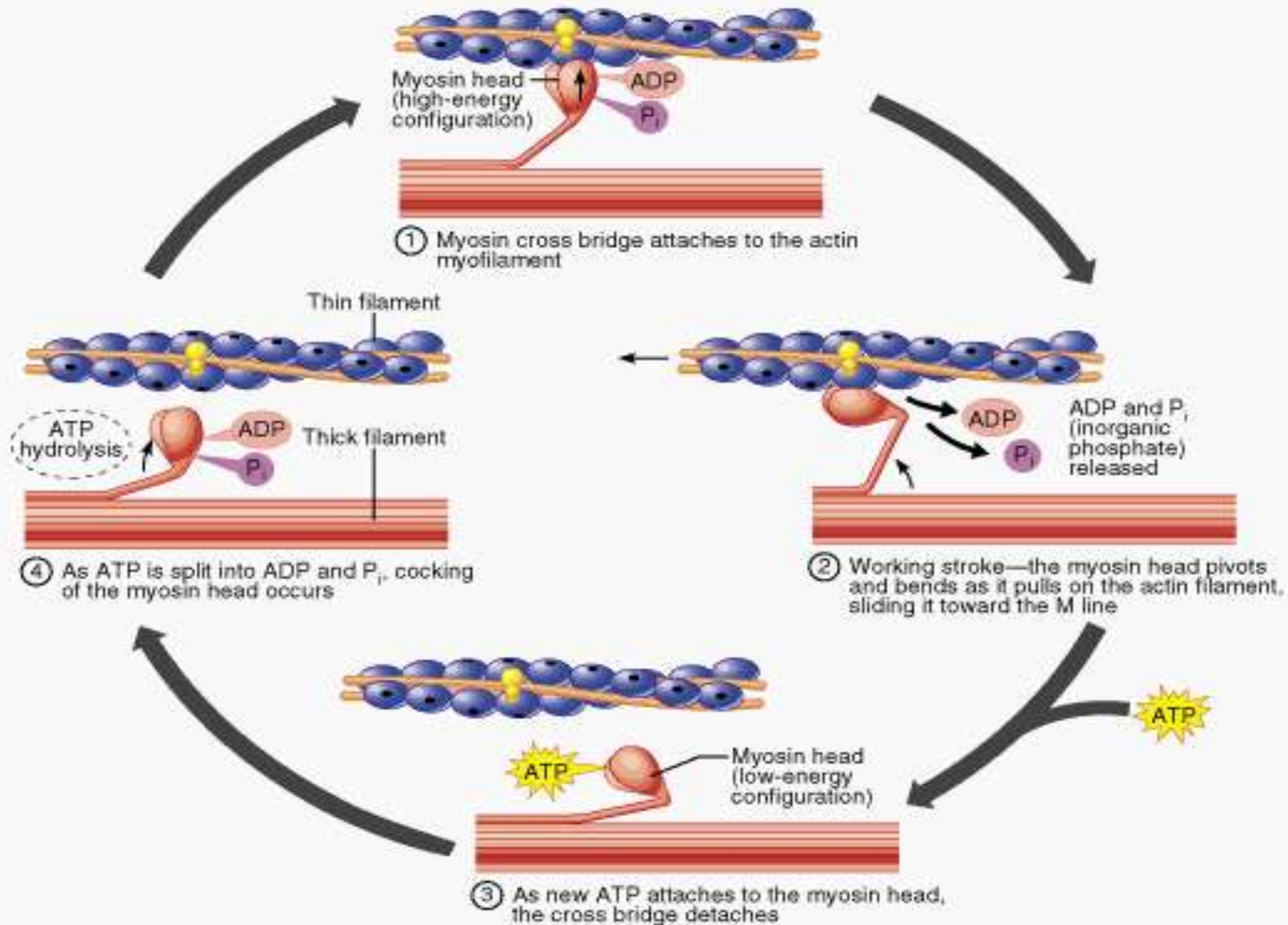
The Muscular System

Sliding Filament Theory (cont)

Step 6: The tropomyosin then regains its position as an inhibitor for the cross bridge binding site.

Step 7: The muscle relaxes.

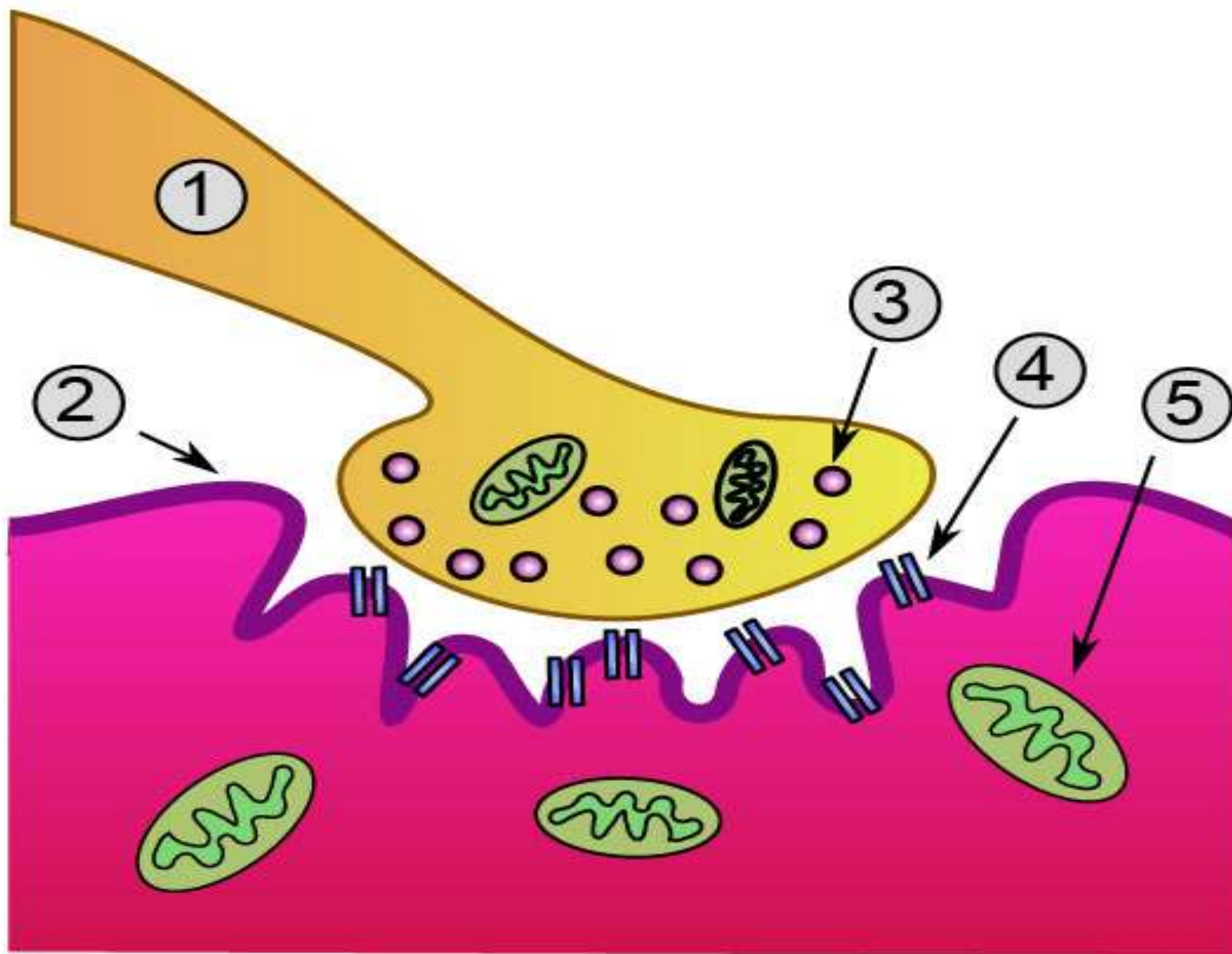
Breakdown of ATP and Cross-Bridge Movement During Muscle Contraction



The Muscular System

The Anatomy of a Muscle Contraction (cont)

- The contraction of skeletal muscle is stimulated by a *motor neuron*.
- A motor neuron is a nerve fiber which transmits nerve impulses from the brain to the neuromuscular junction, or the region between the neuron and the muscle fiber.



The Muscular System

Steps to Propagating Nerve Signals

Step 1: Signal is created by the brain and travels down the motor neuron.

Step 2: The signal causes a depolarization (changes the charge) of the cell membrane of the nerve.

The Muscular System

Step 3: The change in charge causes a release of Calcium ions which in turn triggers the release of acetylcholine (a neurotransmitter).

Step 4: The acetylcholine floods the neuromuscular junction (region between the nerve and muscle aka NMJ) and depolarizes the motor end plate (portion of muscle fiber along the NMJ).

The Muscular System

Step 5: The release of acetylcholine causes calcium ions to be released in the muscle and the calcium binds to the tropomyosin.

***The motor neuron and many skeletal muscles that it controls is called a **motor unit**.

The Muscular System

- These actions are powered by ATP, which lasts about 6 seconds in the muscle.
- It must constantly be regenerated by cellular respiration.
- Cramping and muscle fatigue are seen after long periods of strenuous activity because:
 - Oxygen is depleted rapidly.
 - Cellular respiration without oxygen is an anaerobic process called **lactic acid fermentation**.

The Muscular System

Muscular Response

- Skeletal muscles require a threshold stimulus of + 30 millivolts (mV).
- A stimulus below this will **NOT** cause a contraction.
- Muscle response is all or nothing, if threshold is met then a full contraction will occur.

The Muscular System

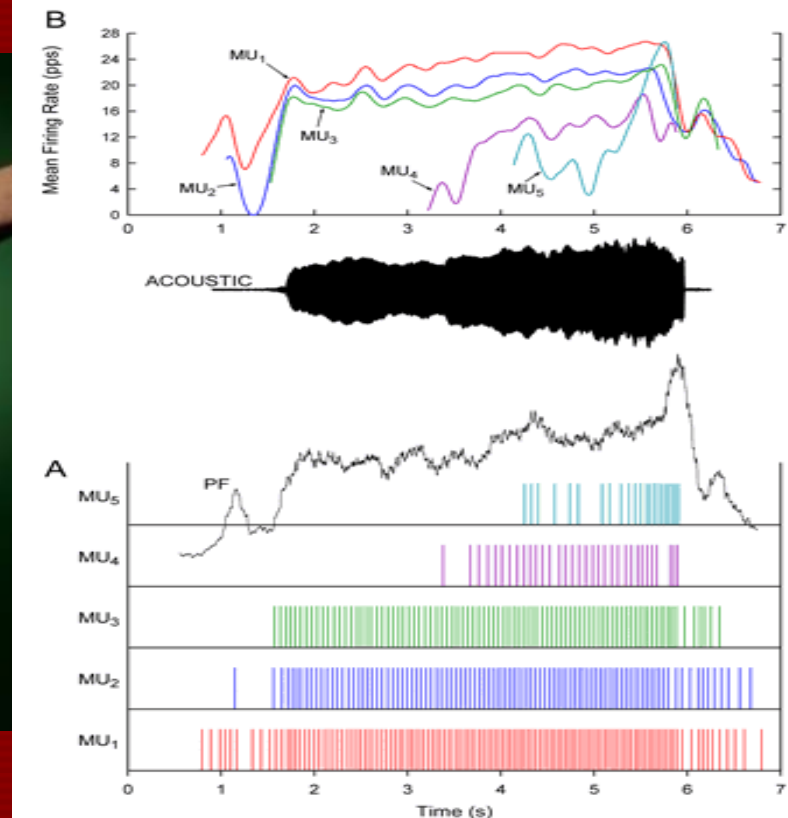
Muscular Response (cont)

- Muscle which are inactive for long periods of time can undergo the staircase effect.
- The *staircase effect* is short periods of muscle contraction with rest periods in between.
- The muscle however requires a constant threshold stimuli.

The Muscular System

Muscular Response (cont)

- Doctors use a *myogram* to monitor muscle response.



The Muscular System

Types of Contractions

- *Isotonic contraction* is when the muscle contracts and its attachment moves.
- *Isometric contraction* is when the muscle contracts and its attachment does NOT, also called straining.



The Muscular System

Types of Muscle Fibers

- *Slow twitch muscle fibers* are red in color because they contain large amounts of the hemoglobin derivative **myoglobin**.
 - These muscles undergo constant strain and require more energy.
 - They can work for longer periods of time without fatiguing.

The Muscular System

Types of Muscle Fibers (cont)

- *Fast twitch muscle fibers* are called white fibers because they have less myoglobin and therefore less oxygen.
 - The strain felt by these muscles is less so the energy requirements are less.



The Muscular System

Muscles and Aging

- As you age muscle tissue breaks down.
- By the age of 80 over 50% of your muscle tissue will be replaced by connective and adipose tissue.

The Muscular System

Smooth Muscle

- The contraction mechanism for smooth muscle is very similar to skeletal muscle.
- The primary difference is in the amounts of SR and TT
- *Calmodulin* replaces tropomyosin as the inhibitor for smooth muscle contractions.

The Muscular System

Smooth Muscle (cont)

- There are 2 types of smooth muscle:
 - 1.) *Multi-unit smooth muscle* allows for rapid and vigorous contraction and it is found in the irises of the eyes and the walls of the blood vessels.
 - 2.) *Visceral smooth muscle* contract in a slow and sustained manner and it makes up the walls of hollow organs.
 - This type of contraction is called *peristalsis*.

The Muscular System

Cardiac Muscle

- Cardiac muscle is uninucleated muscle found only in the heart.
- They are joined end to end by intercalated discs.
- The contraction is rapid and rhythmic.

The Muscular System

Cardiac Muscle (cont)

- The contraction mechanism and microanatomy of cardiac muscle is almost identical to skeletal muscle.
- The only difference is cardiac only has one nuclei whereas skeletal is multi-nucleated.